Asiatic citrus psyllid – a biosecurity threat

Background

Fig. 1. Adult and nymphal ACP feeding on citrus.

The Asiatic citrus psyllid (ACP – Fig. 1), *Diaphorina citri*, is a major pest of citrus in North and South America, throughout Asia, and some South-Pacific islands (e.g. north-western Papua New Guinea). While ACP may cause damage to flushing citrus in its own right, its role as a vector of huanglongbing (HLB) (also called citrus greening) is of great importance when both are present. This bacterial disease (*Candidatus* Liberibacter asiaticus) is considered by many to be the most important and damaging disease of citrus in the world and has only two main vectors: ACP and African citrus psyllid, although recent evidence suggests other psyllids (*Cacopsylla citrisuga* – pomelo psyllid, and *Diaphorina communis*) can acquire and perhaps transmit the disease [5, 7]. None of these psyllid species, nor HLB are currently found in Australia, but would present a significant economic threat to citrus growers if it were to become established. While other psyllids have been reported on citrus around the world, only ACP and African citrus psyllid are significant pests [10].

ACP was identified in the Northern Territory in 1915 but is presumed to have been fortuitously eradicated by the removal of all citrus plants in the area during a citrus canker eradication program that ran between 1916 to 1922 [1]. Recent surveys have confirmed that ACP is not present in the Northern Territory [1]. In fact, citrus is not known to be a host of any species of psyllid across Australia [3]. Therefore, discovery of any psyllid on citrus should be reported to your local biosecurity organisation immediately as it may be possible to eradicate the population.

Damage and impact

Damage caused directly from ACP can be quite serious. Nymphs can only survive on new, flushing growth; adults can survive and feed on new and old plant growth. New growth is most severely damaged; causing curling, notching and deformed growth [10]. ACP is a sap-sucking insect and nymphs and females excrete tube-like, waxy white material [13]. Males excrete liquid honey dew (which is essentially sugary, plant sap). Black-sooty mould may result and cause plants to become unsightly. Feeding by nymphs often results in leaf abscission and sometimes death of entire shoots [22]. Feeding nymphs inject a toxin which can cause death in the apical meristem, also resulting in reduced shoot elongation [22]. Feeding by a single nymph for less than 24 hours can cause a distinctive and permanent deformation which becomes more pronounced as the leaf expands [22]. As such, damage from relatively low populations of nymphs remain visible long after the insects become absent.

Of greater importance is ACP's ability to efficiently vector HLB. Symptoms of HLB include yellow shoots, leaf and fruit drop, twig dieback and leaf chlorosis and mottling (superficially resembling zinc deficiency, but leaf mottling crosses leaf veins, whereas zinc deficiency runs along veins). Trees infected by HLB become stunted, sparsely foliated and may bloom off-season. Trees produce lopsided, hard fruit with small, dark aborted seeds. The juice has a bitter taste and does not colour in the usual fashion, hence the name citrus "greening". Trees may die within 5-8 years. There are currently no known treatments which are capable of removing HLB once a plant has become infected [2].

General biology

Adults are about 3-4 mm in length, have a brown body and light brown head. Their abdomens have three colour groups: grey/brown, blue/green and orange/yellow, however these groups are not known to be of much biological value in discerning individuals that have mated and are not associated with particular seasons or other known variables [31]. Both males and females become reproductively active within 2-3 days and females start laying eggs about a day after mating [30]. A female can lay between 400 and 850 eggs over her lifetime [25, 29]. This number may be lower on certain host plants, climates and regions [25]. In addition, fewer eggs are laid below 40% relative humidity [27]. Females may live between 40-50 days [29]. Adults are poor fliers, generally only flying about 30-100 m at a time, but long distance dispersal can occur with repeated short-distance flights and with the aid of wind [13]. Adults rest and feed on leaves and shoots, holding their bodies at about a 45° angle from the plant surface.

Eggs are light yellow/orange, almond shaped and laid on tips of growing shoots or between unfurling leaves [21] when temperatures are between 16 and 41°C [14]. Eggs hatch after about 2-8 days at 18-32°C, 4 days at 25°C [24, 29]. Nymphs feed on growing shoots and cannot survive without them. Nymphs range in size between 0.3 and 1.7 mm [21] and develop into adults in about 9 to 36 days, depending on host plant and temperature [24, 28, 29]. Nymphs can not develop into adults at constant temperatures of 15°C or below, while about 80% mortality is observed at constant temperatures of 32.5°C; between these temperatures, high survival is observed [23]. Small nymphs are very sedentary and move only when disturbed or overcrowded, but larger nymphs and adults are more mobile [29]. In general, however, nymphs do not move between plants [18]. Adults, nymphs and eggs can survive brief periods at sub-zero

Fig. 3. Damage caused by large numbers of ACP (above) and black-sooty mould and waxy tubules on citrus leaves.

temperatures, i.e. several hours at -5 to -8°C [14]. Optimum temperatures range from about 25-28°C. In North America, the southeastern quadrant of trees had significant higher numbers of ACP [26], perhaps indicating a preference to be present in sunny areas of the tree. In Brazil, it has been shown to be more abundant 1-2 m from the ground than below or above these heights [6].

ACP may feed on a large number of host plants from Rutaceae, but most very good host plants are found in the genera *Citrus*, *Murraya* and *Citropsis* [10]. Some plant species within Rutaceae are moderate or poor hosts, others are not hosts at all. Even among good hosts, some species and varieties are better than others. For example, some of the highest lifetime oviposition rates are on grapefruit (about 850) [29], whereas about 350 are laid on orange jessamine and less than 200 on Sunki mandarin [24].

Fig. 4. ACP eggs laid on the growing tip (above) and nymphs (below) excreting white waxy tubules.

ACP and HLB

HLB is a phloem inhabiting bacteria which can be transmitted by grafting [4], psyllid vectors and occasionally through seed **[10]**, but not usually [4, 15]. The relationship between ACP and HLB transmission is complex and remains somewhat unclear. The most important method by which ACP acquires HLB is through feeding on infected plants as nymphs or adults. Adults may also acquire the bacteria during mating (uninfected females can acquire the disease by mating with an infected male, but the opposite is not the case [20]) and eggs laid by infected females may also have the bacteria, both at relatively low levels; it remains unknown if such individuals can transmit the disease [13]. Under ideal scenarios in India, adult ACP feeding on infected citrus for as little as 15 minutes can acquire HLB (although 30-60 minutes increased the rate acquiring the bacteria). The bacteria appears to require 8-12 days incubation within adult ACP before it can be transmitted to a new host plant [4], after which ACP can transmit it to uninfected plants by feeding on them for as little as 24 hours [4]. Once HLB is acquired, ACP carrying the disease remain capable of transmitting it for the rest of their life [4]. However, there appears to be differences in the rate at which ACP can transmit the disease. For example, research in Japan has shown that some adults that acquire HLB are unable to transmit it to uninfected plants and only individuals that acquire the disease as nymphs are then able to transmit the disease as adults [17]. Differences in the behaviour of the insect-disease interactions may result from the origin and strain of the pathogen and or psyllid. The number of infected insects feeding on an uninfected plant increases the likelihood that the disease is transmitted [4, 9].

Research has shown that ACP adults are more attracted to infected plants compared to uninfected plants. However, once adults have fed on infected plants they disperse and are more likely to settle on non-infected plants [19]. Unfortunately this tendency could increase the rate at which HLB is spread across a landscape.

Of utmost importance is that trees infected with HLB are not easily detected and may remain completely unknown until symptoms develop. Recent research indicates that trees may take one to several years to develop symptoms from the time of original transmission [18]. The long delay in detectability may result from low concentrations of the bacteria, uneven distribution of the organism in non-symptomatic tissue and seasonal changes in bacterial load in infected trees (more psyllids appear to be infected with the bacteria in fall than other seasons [18]). As a result, detection of HLB overseas has often come too late to effectively eradicate the disease, as it had already become widespread [18].

Monitoring for ACP

As stated above, there are no psyllids that are found on citrus in Australia. Therefore, any psyllid found on citrus should be treated as a suspect new introduction and your local biosecurity organisation contacted immediately. Monitoring for ACP should focus on high risk host plants, e.g. species from *Citrus*, *Murraya* and *Citropsis*. While adults can be found on old leaves at any time of year, population increase is closely aligned to periods when host plants are flushing, because eggs are only laid on new growth and nymphs require new growth to survive. For this reason, *Murraya* species should be inspected on a more regular basis than other host plants with more distinct periods of new growth. In North America, large populations are often seen during late spring through mid-summer, but outbreaks can occur any time of year under the right environmental conditions when young flushing shoots are available [11]. For the nursery industry this is particularly important because growing conditions can be modified to promote new growth through much of the year.

Damage to growing tips of *Citrus*, *Murraya* and related plants should prompt examination for the exact cause of damage. Whenever a pest is found on the flushing leaves of citrus and other host plants, look closely to ensure that it is not a psyllid prior to completing management actions. Adults holding their bodies at a 45° angle from the plant and or nymphs producing a curly white waxy excretion should be treated as a suspect ACP, although other signs should also be treated with suspicion.

Fig. 5. Symptoms of HLB on citrus. Photos by Andrew Miles (DAFF)

Management of ACP overseas

Production and retail nurseries are ideal growing environments for populations of ACP over much of Australia. Citrus trees often have frequent, if not continuous flushing and may have very moderate winters which will encourage ACP significantly [18]. Management of ACP in the absence of HLB overseas can be achieved by ensuring that appropriate chemical products protect flushing growth. A large number of insecticides are used overseas against ACP, e.g. carbamates, neonicotinoids, pyrethroids, organophosphates, immature growth regulators, horticultural oils and others [9]. A common product used against nymphal ACP is a soil drench of imidacloprid which can give 2-3 months control of ACP [16]. Imidacloprid (as a foliar application) is also the only pesticide that is currently registered (as of January 2013) for any psyllid species on ornamental or citrus crops in Australia. Application of foliar pesticides in the overwintering stage can reduce populations more significantly than during periods in which plants are actively growing because only adults are present and they are not reproducing. They also have relatively little impact on predator populations [9]. Frequent chemical applications overseas has resulted in the occurrence of pesticide resistance to neonicotinoids, organophosphates and pyrethroids [9].

Fig. 6. Adult ACP at characteristic 45° angle.

Trends overseas indicate that eventually, once ACP is present, HLB will follow. The presence of both disease and vector is far more serious than ACP alone and has significant management implications. Management of HLB is difficult because trees can not be cured and symptoms do not develop for months or even years [18]. Intensive applications of pesticides during flushing growth combined with use of only approved nursery stock grown free of HLB and aggressive removal of infected trees can reduce the rate of newly infected trees but generally is not sufficient to fully manage the organisms [13].

Production nurseries in Florida, where both ACP and HLB are present, generally had very good hygiene, management and very low levels of ACP. Retail nurseries, on the other hand, often were found with ACP and were confirmed as a source of spread of HLB to new areas. The full extent of the spread caused by sales of infected stock then takes years to be fully realised. In such cases, presence of ACP on a tree can be assumed to indicate that HLB is also present [18]. *Murraya* species, which tend to flush more continuously than citrus, must be treated in a similar manner as they also are susceptible to HLB, and ACP feeding on infected plants can transmit the disease [8, 18]. It has been suggested that, without management of ACP and removal of infected trees, 100% infection will take only about 8 years [2].

There is considerable research into developing ACP- and disease-resistant citrus trees but such varieties are not yet available [13]. In Florida, nursery producers that wish to grow *Citrus* and *Murraya* species must follow strict guidelines, the most important of which is that stock must be propagated in an approved greenhouse structure including enclosed sides and tops to exclude insects with positive pressure and double door entries. Trees infested with ACP at retail nurseries in Florida are subject to quarantine action [i].

If you see this pest

If you see or suspect that you have seen any psyllid on citrus contact your local biosecurity organisation or the Exotic Plant Pest Hotline (1800 084 881). Do not move the plant material with ACP. Research has shown that ACP can survive up to 10 days on detached stems and up to 20-30 days on detached stems with fruit [12]. Thus care must be taken when disposing of plants that have been infested with ACP such that they are not spread to new areas inadvertently. There is no better way to manage ACP than to keep it out of Australia. Currently there is no management strategy of ACP and HLB that is completely successful.

[i] The entire report can be found at: <https://www.flrules.org/gateway/ChapterHome.asp?Chapter=5B-62>

This document was prepared by Andrew Manners (Agri-science Queensland, Department of Agriculture, Fisheries and Forestry, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) as part of NY11001 Plant health biosecurity, risk management and capacity building for the nursery industry. Thanks go to Michael Rogers (University of Florida) for providing images used in this document and John Duff and Lindy Coates for providing comments on earlier versions of this factsheet.

References

1. Bellis, G., D. Hollis, and S. Jacobson, 2005. Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera : Psyllidae), and huanglongbing disease do not exist in the Stapleton Station area of the Northern Territory of Australia. *Australian Journal of Entomology* **44**: 68-70.
2. Bove, J.M., 2006. Huanglongbing: A destructive, newly-emerging, century-old disease of citrus. *Journal of Plant Pathology* **88**: 7-37.
3. Broadbent, P., 2000. Australian citrus dieback, In *Compendium of Citrus Diseases, Second Edition*, L.W. Timmer, S.M. Garnsey, and J.H. Graham, Editors. APS Press: St. Paul, Minnesota, USA. 46.
4. Capoor, S.P., D.G. Rao, and S.M. Viswanath, 1974. Greening disease of citrus in the Deccan Trap Country and its relationship with the vector, *Diaphorina citri* Kuwayama. *Proceedings of the Sixth Conference of the International Organization of Citrus Virologists.*: 43-49.
5. Cen, Y., L. Zhang, Y. Xia, J. Guo, X. Deng, W. Zhou, R. Sequeira, J. Gao, Z. Wang, J. Yue, and Y. Gao, 2012. Detection of '*Candidatus* Liberabcter asiaticus' in *Cacopsylla* (*Psylla*) *citrisuga* (Hemiptera: Psyllidae). *Florida Entomologist* **95**: 304-311.
6. Chiaradia, L.A., J.M. Milanez, M.A. Smaniotto, and M.R.F. Davila, 2008. Population fluctuation and capture height of *Diaphorina citri* in citrus orchard. *Revista de Ciencias Agroveterinarias* **7**: 157-159.
7. Donovan, N.J., G.A.C. Beattie, G.A. Chambers, P. Holford, A. Englezou, S. Hardy, Dorjee, P. Wangdi, Thinlay, and N. Om, 2012. First report of '*Candidatus* Liberibacter asiaticus' in *Diaphorina communis*. *Australasian Plant Disease Notes* **7**: 1-4.
8. Gasparoto, M.C.G., R.B. Bassanezi, L. Amorim, L.H. Montesino, S.A. Lourenco, N.A. Wulff, D.C. Teixeira, A.G. Mariano, E.C. Martins, A.P.R. Leite, and A. Bergamin Filho, 2010. First report of '*Candidatus liberibacter americanus*' transmission from *Murraya paniculata* to sweet orange by *Diaphorina citri*. *Journal of Plant Pathology* **92**: 546-546.
9. Grafton-Cardwell, E.E., L.L. Stelinski, and P.A. Stansly, 2013. Biology and management of asian citrus psyllid, vector of the huanglongbing pathogens. *Annual Review of Entomology* **58**: 413-32.
10. Halbert, S.E. and K.L. Manjunath, 2004. Asian citrus psyllids (Sternorrhyncha : Psyllidae) and greening disease of citrus: A literature review and assessment of risk in Florida. *Florida Entomologist* **87**: 330-353.
11. Hall, D.G. 2008 Biology, history and world status of *Diaphorina citri*. In *Proceedings of the Taller Internacioinal Sobre Huanglongbing y el Psilido Asiatico de los Citricos, 7-9 May 2008*. Hermosillo, Sonora: Available at: <http://www.concitver.com/huanglongbingYPsilidoAsiatico/Memor%C3%ADa-2%20Hall.pdf>.
12. Hall, D.G. and G. McCollum, 2011. Survival of adult asian citrus psyllid, *Diaphorina citri* (Hemiptera: Psyllidae), on harvested citrus fruit and leaves. *Florida Entomologist* **94**: 1094-1096.
13. Hall, D.G., M.L. Richardson, E.-D. Ammar, and S.E. Halbert, 2013. Asian citrus psyllid, *Diaphorina citri*, vector of citrus huanglongbing disease. *Entomologia Experimentalis Et Applicata* **146**: 207-223.
14. Hall, D.G., E.J. Wenninger, and M.G. Hentz, 2011. Temperature studies with the Asian citrus psyllid, *Diaphorina citri*: Cold hardiness and temperature thresholds for oviposition. *Journal of Insect Science* **11**.
15. Hartung, J.S., S.E. Halbert, K. Pelz-Stelinski, R.H. Brlansky, C. Chen, and F.G. Gmitter, 2010. Lack of evidence for transmission of '*Candidatus* Liberibacter asiaticus' through citrus seed taken from affected fruit. *Plant Disease* **94**: 1200-1205.
16. Ichinose, K., D.V. Bang, D.H. Tuan, and L.Q. Dien, 2010. Effective Use of Neonicotinoids for Protection of Citrus Seedlings From Invasion by Diaphorina citri (Hemiptera: Psyllidae). *Journal of Economic Entomology* **103**: 127-135.
17. Inoue, H., J. Ohnishi, T. Ito, K. Tomimura, S. Miyata, T. Iwanami, and W. Ashihara, 2009. Enhanced proliferation and efficient transmission of Candidatus Liberibacter asiaticus by adult Diaphorina citri after acquisition feeding in the nymphal stage. *Annals of Applied Biology* **155**: 29-36.
18. Manjunath, K.L., S.E. Halbert, C. Ramadugu, S. Webb, and R.F. Lee, 2008. Detection of '*Candidatus* Liberibacter asiaticus' in *Diaphorina citri* and its importance in the management of citrus huanglongbing in Florida. *Phytopathology* **98**: 387-396.
19. Mann, R.S., J.G. Ali, S.L. Hermann, S. Tiwari, K.S. Pelz-Stelinski, H.T. Alborn, and L.L. Stelinski, 2012. Induced release of a plant-defense volatile 'deceptively' attracts insect vectors to plants infected with a bacterial pathogen. *Plos Pathogens* **8**.
20. Mann, R.S., K. Pelz-Stelinski, S.L. Hermann, S. Tiwari, and L.L. Stelinski, 2011. Sexual transmission of a plant pathogenic bacterium, *Candidatus* Liberibacter asiaticus, between conspecific insect vectors during mating. *PloS one* **6**.
21. Mead, F.W., 1977. The Asiatic citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae). *Entomology Circular, Division of Plant Industry, Florida Department of Agriculture and Consumer Services* **No. 180**.
22. Michaud, J.P., 2004. Natural mortality of Asian citrus psyllid (Homoptera : Psyllidae) in central Florida. *Biological Control* **29**: 260-269.
23. Nakata, T., 2006. Temperature-dependent development of the citrus psyllid, *Diaphorina citri* (Homoptera : Psylloidea), and the predicted limit of its spread based on overwintering in the nymphal stage in temperate regions of Japan. *Applied Entomology and Zoology* **41**: 383-387.
24. Nava, D.E., M.L.G. Torres, M.D.L. Rodrigues, J.M.S. Bento, and J.R.P. Parra, 2007. Biology of *Diaphorina citri* (Hem., Psyllidae) on different hosts and at different temperatures. *Journal of Applied Entomology* **131**: 709-715.
25. Paiva, P.E.B. and J.R.P. Parra, 2012. Life table analysis of *Diaphorina citri* (Hemiptera: Psyllidae) infesting sweet orange (*Citrus sinensis*) in Sao Paulo. *Florida Entomologist* **95**: 278-284.
26. Setamou, M., D. Flores, J.V. French, and D.G. Hall, 2008. Dispersion patterns and sampling plans for *Diaphorina citri* (Hemiptera : Psyllidae) in citrus. *Journal of Economic Entomology* **101**: 1478-1487.
27. Skelley, L.H. and M.A. Hoy, 2004. A synchronous rearing method for the Asian citrus psyllid and its parasitoids in quarantine. *Biological Control* **29**: 14-23.
28. Teck, L., F. Abang, A. Beattie, K. Heng, and W. King, 2011. Influence of host plant species and flush growth stage on the Asian citrus psyllid, *Diaphorina citri* Kuwayama. *American Journal of Agricultural and Biological Sciences* **6**: 536-543.
29. Tsai, J.H. and Y.H. Liu, 2000. Biology of Diaphorina citri (Homoptera : Psyllidae) on four host plants. *Journal of Economic Entomology* **93**: 1721-1725.
30. Wenninger, E.J. and D.G. Hall, 2007. Daily timing of mating and age at reproductive maturity in *Diaphorina citri* (Hemiptera : Psyllidae). *Florida Entomologist* **90**: 715-722.
31. Wenninger, E.J. and D.G. Hall, 2008. Daily and seasonal patterns in abdominal color in *Diaphorina citri* (Hemiptera : Psyllidae). *Annals of the Entomological Society of America* **101**: 585-592.